Some criteria of making decisions in pedestrian evacuation algorithms.

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Abstract

The main goal of this paper is to introduce a model of inteligent behavior in pedestrian dynamics using cellular automata. Authors take into account classical situation of large room evacuation, where several exits are available. Presented model includes some criteria of making decisions by a particular pedestrian. Proposed criteria are: distance to all exits, density of crowd in each exit neighborhood, throughput of particular exit and following the other persons.

1. Introduction

Over the last years the study of pedestrian dynamics has become an attractive area of research. Possibilities connected with nowadays computing technology make it possible to simulate behavior of great pedestrian groups. Now we can observe tendency of creating microscopic models, when behavior of particular person is taken into account.

Nowadays, two simulation technologies seem to be most popular: the first is *Social Forces Method* and the second is *Cellular Automata*.

Social Forces is based on *Molecular Dynamics* and the method was introduced by Helbing et al. [8], [11], [10], [9].

Cellular Automata method was proposed for pedestrian dynamics by Fukui & Ishibashi [5] and simultaneously by Blue & Adler [1].

This work deals with Cellular Automata (CA) models, where decision process in pedestrian movement is taken into consideration.

2. Review of literature – CA models

Let us mention some recent works deal with pedestrian dynamics.

In [2] Dijkstra et al. presented multi–agent model of freeway traffic, when all pedestrians are presented as autonomous agents.

In [6], Gloor et al. have proposed model of hikers in Alps. A space in the model was discretized in the form of two layers: the first is CA lattice, and the second is a graph with connections among cells.

In a model by Narimatsu et al. [14] collision avoidance in two–direct pedestrian movement are presented. Pedestrians walk longwise corridor in two opposite directions and they learn some patterns to avoid collisions.

A paper by Morishita & Shiraishi deals with pedestrian flow in a concourse of the stations. An aim of the model is to verify an effectiveness of billboards, as a medium for advertisement [13]. Authors propose an evaluating index for billboards set along along the pathway in the concourse.

In [4] new model of crowd behavior is proposed. The presented model is based on Festinger's Social Comparison Theory.

Another model sociological is presented in works [7], [19], [18]. People are represented as ellipses and Hall's Proxemics theory is the main part of the proposed model.

In the works [15],[16], some Cellular Automata models of pedestrian dynamics in normal and evacuation situations are introduced.

3. Proposed model

3.1. Model formalization

Formalization of nonhomogeneous CA is based on term *extended cellular automaton* [3] is defined as the seventuple:

$$CAL_{const} = (C, R_p, \eta, S, CON, r, f) \quad (1)$$

where:

C	-	set of cells $c \in C$
R_p	-	adjacent relation
η	-	neighborhood function
S	-	set of cells' states
CON	-	set of cells configurations
r	-	local rule
f	-	transition function

More complete description of extended CA definition could be found in works [3], [16].

3.2. Description of the model

Proposed model are based on asynchronous and inhomogeneous cellular automata. Space is represented as a lattice with square cells. Simulated situation is large room evacuation by group of pedestrian. The room topology includes several exits. Pedestrian traffic is registered at discrete time intervals. These people leave the room in discrete time intervals, through accessible exits.

Each pedestrian makes a decision: *which movement direction (toward an exit) is the most optimal* (It allows to leave the room in the shortest time). Pedestrians consider four criteria (according to experiments[12], [16]):

- distance to all exits,
- crowd density in each exit neighborhood,
- following other persons,
- throughput of particular exit.

All mentioned criteria are included in a following gain function:

$$C_{ij} = w_d(1 - d_i(e_j)) + w_\rho(1 - \rho(e_j)) + w_f f(e_j) + w_t t(e_j) \quad (2)$$

$$\rho(e_j) = \frac{1}{|N(e_j,\lambda)|} \sum_{k=1}^{|N(e_j,\lambda)|} s(c_k) \quad (3)$$

where:

C_{ij}	-	a cost of decision to use an exit e_j by *i*-th pedestrian
$i = 1, 2, ..., \|L\|$	-	index of pedestrians
$j = 1, 2, ..., \|E\|$	-	index of exits
$d_i(e_j)$	-	normalized distance of *i*-th pedestrian to *j*-th exit, $d_i(e_j) \in [0; 1]$
$\rho(e_j)$	-	crowd density round *j*-th exit defined by (3), $\rho(e_j) \in [0; 1]$
$f(e_j)$	-	normalized “fragrance” of an exit e_j, $f(e_j) \in [0; 1]$
$t(e_j)$	-	normalized throughput of anexit e_j, $t(e_j) \in [0; 1]$
w_d, w_ρ, w_f, w_t	-	criterions weights, $w \in [0; 10]$
$N(e_j, \lambda)$	-	Moore neighborhood of a radius λ
$s(c_k)$	-	state of *k*-th cell (where 0 means vacant cell and 1 means occupied cell)

For experiment purposes different combinations of criterions were considered. Corresponding element of equation (2) had to be omitted when criterion was not used by particular experiment. I.e.: if only distance and throughput was considered w_ρ and w_f were equalled 0. Proposed gain function is calculated in every timestep, for all possible decisions, which particular pedestrian would make. By “decision” one should understand selection of certain exit, with greatest value of the gain function.

While criterions of distance and crowd density given above are clear, remaining two criterions require further explanation.

Fragrance of exit measures how attractive particular exit is for pedestrians. When more pedestrians attend exit, it becomes more attractive for remaining persons. In that way successors tend to follow their predecessors.

Throughput of exit tells how “wide” particular exit is. Exit cells can be treated as cluster members, when they keep direct contact with other exit cells. Two cells are in contact, when they each other belong to their Moore neighborhoods of radius 1.

3.3. Movement algorithm

Movement algorithm of *a particular pedestrian*, for one time-step-slice is presented below:

1. For selecting of exit, towards which you will direct, evaluate components of a gain function: distance, crowd density around exit, fragrance and throughput of exit.
2. Select exit, for which a gain function has a maximum.
3. Determine potential field related to selected exit e_j.

4. Check value of potential generated by exit e_j in cell which you occupy.

5. Determine set of cells belonging to Moore's neighborhood of occupied cell. Determine subset of vacant cells which potential value is *better* than potential of cell which you occupy.

6. Is this subset nonempty? If yes, move to randomly selected cell of this subset and stop. Otherwise follow next step.

7. Determine new subset of vacant cells with potential value equal to potential value of cell which you could occupy.

8. Is this subset nonempty? If yes, move to randomly selected cell of this subset and stop. Otherwise you cannot move - you have to stay on a current cell.

4. Simulation results

A computer application based on the described model has been made. Some characteristic examples of proposed model running are shown on figures below. Figure 1 shows initial allocation of pedestrians in a room. Pedestrians are represented as green circles with black arrows and they are placed inside a room. Black cells represent walls or obstacles. White, pink and blue cells belong to Movement Space [16]. Blue cells represent exits.

In a situation, when pedestrians use only distance criterion, they move into the nearest exits. This model is proper for passive pedestrian strategy (i.e. leaving room for normal situation). Figure 2 shows situation when pedestrian take into consideration only distance criterion.

When strategy of pedestrians is more active, they take into consideration some others criteria for choosing the optimal exit. All the time, distance criterion is the main criterion, but others criteria are more and more significant. Following figure 3 presents a situation, when distance criterion has weight value: 3 and throughput has weight value: 1 (i.e. controlled evacuation situation).

5. Conclusions

The presented model is an extension of models presented in works: [15],[17]. In the proposed model pedestrians make decisions on the base of a gain function. The gain function has four criteria: distance to all exits, density of crowd in each exit neighborhood, throughput of particular exit and following the others.

Generally distance to all exits is the most significant criterion, especially for passive pedestrians strategy.

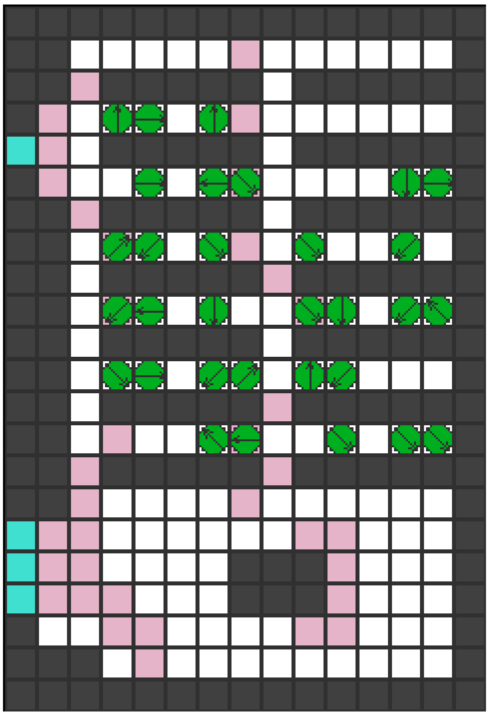

Figure 1. Initial allocation of pedestrians in a room

When strategy of pedestrians become more active (for instance in an evacuation situation) other criteria become to be more significant. In this case, it is possible to use a combination of all proposed criteria.

Qualitative comparison computer simulation results with real experiments results [16] has confirmed initial assumptions. Thus, the presented model requires, of course, full validation process.

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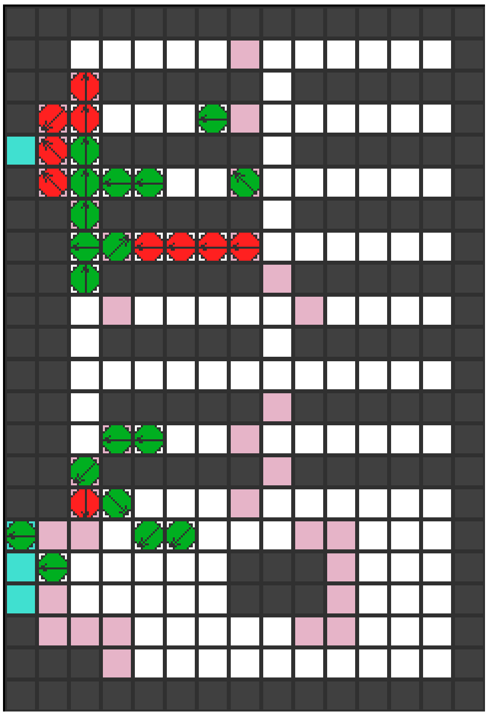

Figure 2. Example of passive pedestrians strategy

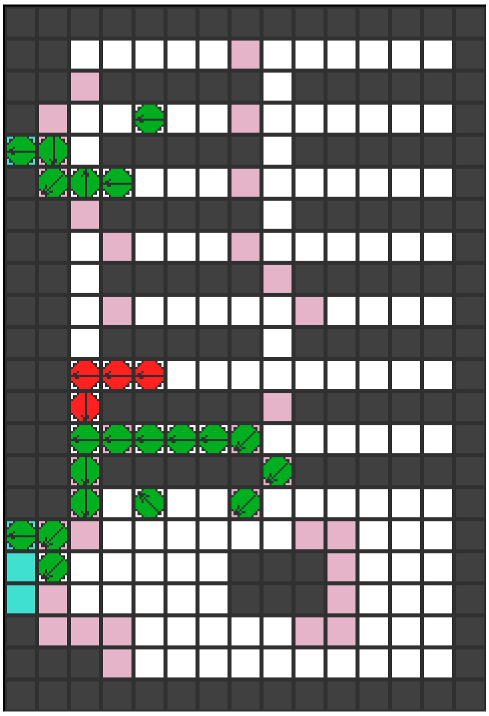

Figure 3. Example of active pedestrians strategy

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